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PRELIMINARY MEASUREMENTS OF AIRCRAFT AIRFRAME NOISE WITH THE NASA CV-990 AIRCRAFT

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16. Abstract

Flight tests were conducted in a CV-990 jet transport with engines at idle power to investigate aircraft airframe noise. Test results showed that airframe noise was measured for the aircraft in the landing configuration. The results agreed well with the expected variation with the fifth power of velocity. For the aircraft in the clean configuration, it was concluded that airframe noise was measured only at higher airspeeds with engine idle noise present at lower speeds. The data show that landing gear and flaps make a significant contribution to airframe noise.

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PRELIMINARY MEASUREMENTS OF AIRCRAFT AIRFRAME

NOISE WITH THE NACA CV-990 AIRCRAFT

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INTRODUCTION

The Noise Control Act of 1972 directs the United States "to promote an environment for all Americans free from noise that jeopardizes their health or welfare." The reduction of aircraft noise is necessary to improve the environment for many Americans. In recent years considerable attention has been given to reducing jet aircraft noise by designing quieter engines, acoustically treating current engine installations, and by developing operational procedures which permit noise abatement takeoffs and approaches. These methods have proved successful in reducing jet aircraft noise. However, the communities around airports are demanding even greater reductions in aircraft noise. Further reductions in aircraft propulsive noise may be feasible, but recent studies and flight tests (refs. 1-4) indicate that the noise reduction attainable on approach may be limited to the level of the airframe noise. Airframe noise is defined as the noise radiated by an aircraft flying through the air without the propulsion system operating. This level has been found to be within 10 EPNdB of approach noise certification levels. Thus a large reduction in aircraft approach noise will require reductions in both the propulsion and airframe generated noise.

The airframe noise is believed to be the result of the turbulence produced by air flowing over and around the aircraft. Regions of turbulent flow are produced as air passes by trailing edges, landing gear cavities, and other airframe discontinuities. The airframe noise source mechanism is not well understood, however, and to reduce airframe noise, its sources must be identified and quantified.

The first flights to investigate airframe noise were made several years ago using gliders and propeller-driven aircraft (ref. 5). The largest aircraft tested was a Convair 240 that weighed approximately 17,700 kg (39,000 lb). The airframe noise signature of an F-106B airplane has also been obtained (ref. 6). Subsequent flight tests were made with a C-5A aircraft, which weighs approximately 273,000 kg (600,000 lb), with the engines at idle power (ref. 7). However, the C-5A tests data were limited to frequencies of less than 400 Hz because of the engines' noise at the higher

frequencies. Prediction techniques for airframe noise have been developed (refs. 8 and 9) which are based in part on the data from references 5-7.

Because the only data on jet transport type aircraft was the C-5A data which was severely limited in frequency, a flight research program was initiated by the NASA in 1972 to further investigate the nature and relative importance of airframe noise source mechanisms. A series of landing approaches was flown at the NASA Dryden Flight Research Center using four aircraft: an Aerocommander, a Jetstar, a CV-990, and a B-747. Results of the Aerocommander and Jetstar tests were presented in reference 1. A brief summary of all the tests is provided in reference 2. The purpose of this paper is to present the detailed results of the CV-990 tests. These tests were conducted in February 1974, on Rogers Dry Lake at NASA Dryden Flight Research Center.

Ideally, airframe noise would be measured during landing approaches flown with the airplane's engines completely shut down. This is somewhat risky, however, since at landing speeds and at altitudes required to obtain meaningful data, there would not be time to restart the engines for a go around in the event of an emergency. Therefore, the CV-990 was flown with all four engines at idle. The primary purpose of the tests was to first determine for what configurations and flight conditions airframe noise could be measured with the CV-990 with engines at idle and to then compare the results obtained with previously published results for other aircraft. Noise measurement instrumentation, the data reduction technique, and the test procedures are described. Overall sound pressure levels (OASPL) and noise spectra for the CV-990 are presented.

Because the engines were at idle during these flight tests, static ground measurements were taken with the engines also at idle in order to have a basis for determining whether the noise measured during flight was predominantly airframe noise or if engine noise was a significant portion of the total noise measured.

TEST AIRCRAFT

The CV-990 used for these tests is a typical long range jet transport and is shown in figure 1. The maximum takeoff weight is 114,760 kg (253,000 lb) and the maximum landing weight is 90,720 kg (200,000 lb). The aircraft is powered by four General Electric CJ805-23B aft-turbofan engines rated at 71,170 N (16,000 lb) thrust each.

INSTRUMENTATION AND DATA REDUCTION

The microphone array for the static ground measurements is shown in figure 2. The tripod-mounted microphones were located in a semi-circular pattern around the airplane at 20° intervals. The microphones were 75 m from the airplane.

For the flight tests, the microphone stations were located relative to the airplane approach ground track as shown in figure 3. Both tripod-mounted and flush-mounted microphones were placed along and perpendicular to a runway on Rogers Dry Lake, which had a smooth hard-packed clay surface.

Condenser microphones with cathode followers and power supplies were used for the tests. The signal from each microphone system was routed through shielded two-conductor cable to a mobile acoustic van, where the data were recorded on a 14-track wideband FM tape recorder. Voice comments describing each test and a broadcast time code were also recorded.

Before and after each day's tests, an acoustic calibration was applied to each microphone. The resulting signal was recorded for use in the data reduction process. In addition, a noise calibration was recorded for each microphone system to aid in the examination of each system's frequency response. The accuracy of the sound pressure levels is estimated to be ±0.5 decibels at all frequencies.

The aircraft's speed over the microphone array was recorded by the flight crew from the cockpit instruments. The airplane's gross weight over the microphones was determined for each approach from the airplane's empty weight and fuel weight.

The aircraft's position during the landing approach was obtained from a tracking radar adjacent to Rogers Dry Lake. To aid in the tracking, a C-band radar transponder was installed on the airplane. A broadcast time code was recorded in parallel with the radar data to correlate the acoustic data with the airplane position data.

The radar data were smoothed and then processed to provide airplane altitude and range information for each microphone station. The time history of the distance between the aircraft and each microphone was then calculated for correlation with the acoustic data.

A one-third octave band spectral analysis of the noise recordings was made with a computer-controlled real-time analyzer that met the FAR part 36 specifications (ref. 10) for equipment used to analyze noise data. The time constant used for the data analysis was one second. The data was scaled, frequency corrections were made, if necessary, and the data were corrected to standard day conditions by using the procedure described in reference 10. When necessary, the data were extrapolated to other than the measurement distances by applying the inverse square of the distance and standard day atmospheric absorption corrections. The overall sound pressure levels (OASPL) and perceived noise levels were calculated from the one-third octave band spectra. The data from the flush-mounted microphones were not corrected for the sound pressure doubling effects inherent in such data, and the tripod-mounted data retain ground reflection effects (ref. 11).

FLIGHT TEST PROCEDURE

The airplane was flown over the microphone array on a glideslope that allowed the airplane to maintain a nearly constant airspeed. This computed glideslope was between 3° and 9°, depending on the airplane configuration and desired airspeed. A controller vectored the aircraft onto the glideslope, which was plotted on a radar plot board. The pilot then flew the aircraft down the predetermined glideslope by using glideslope and ground track deviation information supplied him by the controller along with visual information provided by a VASI light located at the glideslope intersection with the runway. The VASI light was set at the desired glideslope. When the aircraft was approximately 10 sec from the first microphone position, the pilot brought the engines to idle. Thrust was reapplied approximately 10 sec after the airplane passed the last microphones or when it descended below an altitude of approximately 30 m (100 ft), whichever occurred first.

During the flight test the aircraft was flown in the clean or cruise configuration (gear and flaps retracted), the landing configuration (gear and flaps extended), and the descent configuration (flaps extended and gear retracted). For the cruise and landing configurations, flights were made at two different airspeeds in order to examine the variations of noise with airspeed. The flights in the descent configuration were included in order to examine the effects of gear and flaps on the airplane noise.

RESULTS AND DISCUSSIONS

The spectrum for ground static noise with engines at idle is shown in figure 4. The sound pressure level (SPL) in decibels (dB) is shown as a function of third octave band center frequency in Hertz. The data shown were measured at the microphones located just before and just aft of the aircraft wing. (Microphones 5 and 6 in fig. 2.) The important point to note here is the peak in the spectrum at a frequency of 1250 Hz and a secondary peak at 500 Hz. These peaks also appear in the spectra of most of the other microphones and are felt to be characteristic of the engine noise at idle power.

Spectral data from flight test for the aircraft in the cruise or clean configuration (gear and flaps retracted) are shown in figure 5. Spectral data for the aircraft in the landing configuration (gear and flaps extended) are shown in figure 6. The data in these two figures are normalized to a distance of 152.4 m (500 ft) and an aircraft gross weight of 79,380 kg (175,000 lb). The normalization was based on the assumption that the spectral shape remains constant while the spectral level varies directly with the weight and inversely with the square of the distance.

The data shown in figure 5 are for two widely different airspeeds, 190 and 314 knots. A look at the spectra shows a peak at a frequency of 1250 Hz for the 190-knot case. This seems to indicate idle engine noise is indeed

included in the noise for 190 knots. However, there is not a peak at 500 Hz. The spectra for 314 knots airspeed does not have the peak either at 500 or 1250 Hz indicating a predominance of airframe noise. The conclusion to be drawn here is that airframe noise was predominant for the higher speed case, but the noise for 190 knots was a combination of airframe and engine noise.

Data for the landing configuration in figure 6 are given for airspeeds of 160 and 200 knots. These spectra do not have a peak at either 500 or 1250 Hz indicating that airframe noise is predominant in these data. The conclusion here is that for the aircraft in the landing configuration, airframe noise was measured for airspeeds of 160 knots and above.

The noise data are summarized in terms of OASPL in figure 7. It has been concluded previously (ref. 2) that the airframe noise varies directly with the fifth power of velocity. The measured data for both the clean and landing configurations are compared with a V^5 curve. Comparison of the landing configuration data with the V^5 curve clearly shows close agreement. Comparison of the clean configuration noise with the V^5 curve does not show close agreement. This is further evidence of the conclusions drawn from the spectral data that for the landing configuration airframe noise was predominant but for the clean configuration at the lower airspeeds both airframe and engine noise are present.

Spectral data are shown in figure 8 for the aircraft in three configurations in order to illustrate some of the effects of landing gear and flap on the airframe noise. The clean configuration data shown are the 314-knot case (fig. 5), the data for the landing configuration are the 200-knot case (fig. 6), and the data for flaps extended are based on a flight at 190 knots. These data are normalized, as before, with an additional normalization to 200 knots airspeed by assuming the noise varies with V^5. Extension of the landing flaps increased the OASPL by about 13 dB. Extending the landing gear led to an additional 2 dB increment in the noise. Although extension of the landing gear with flaps retracted was not a part of this initial flight test, it is clear that both the gear and flap have a significant effect on the airframe noise.

Variation of airframe noise with slant range is illustrated in figure 9. OASPL is shown as it varies with slant range for both clean and landing configurations. Data from flush-mounted microphones located along the ground track are presented along with data from a line of tripod-mounted microphones located perpendicular to the ground track at distances up to 450 m (1476 ft) off the ground track. The solid symbols represent the noise measured from the flush-mounted ground track microphones. The data indicate that the noise along the ground track exhibits the expected agreement with the inverse square law for both clean and landing configurations. The OASPL for microphones located on a line to the side of the ground track appear to deviate somewhat from agreement with the inverse square law. This is probably due, in part, to the effects of extra ground attenuation.

CONCLUDING REMARKS

Flight tests were conducted in a CV-990 jet transport with engines at idle power to investigate aircraft airframe noise. The results were compared with engine ground static noise in order to detect the presence of airframe noise. Test results showed that airframe noise was measured for the aircraft in the landing configuration at speeds above 160 knots. The results agreed well with the expected variation with the fifth power of velocity. For the aircraft in the clean configuration, it was concluded that airframe noise was measured at an airspeed of 314 knots, but that engine idle noise was present at 190 knots. The data show that landing gear and flaps make a significant contribution to airframe noise. Airframe noise along the aircraft ground track exhibits the expected variance with $h^{\frac{1}{2}}$, but airframe noise measured to the side of the ground track deviates somewhat from variation with $h^{\frac{1}{2}}$. This is probably due to the effects of ground attenuation.

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Figure 1.– CV 990.

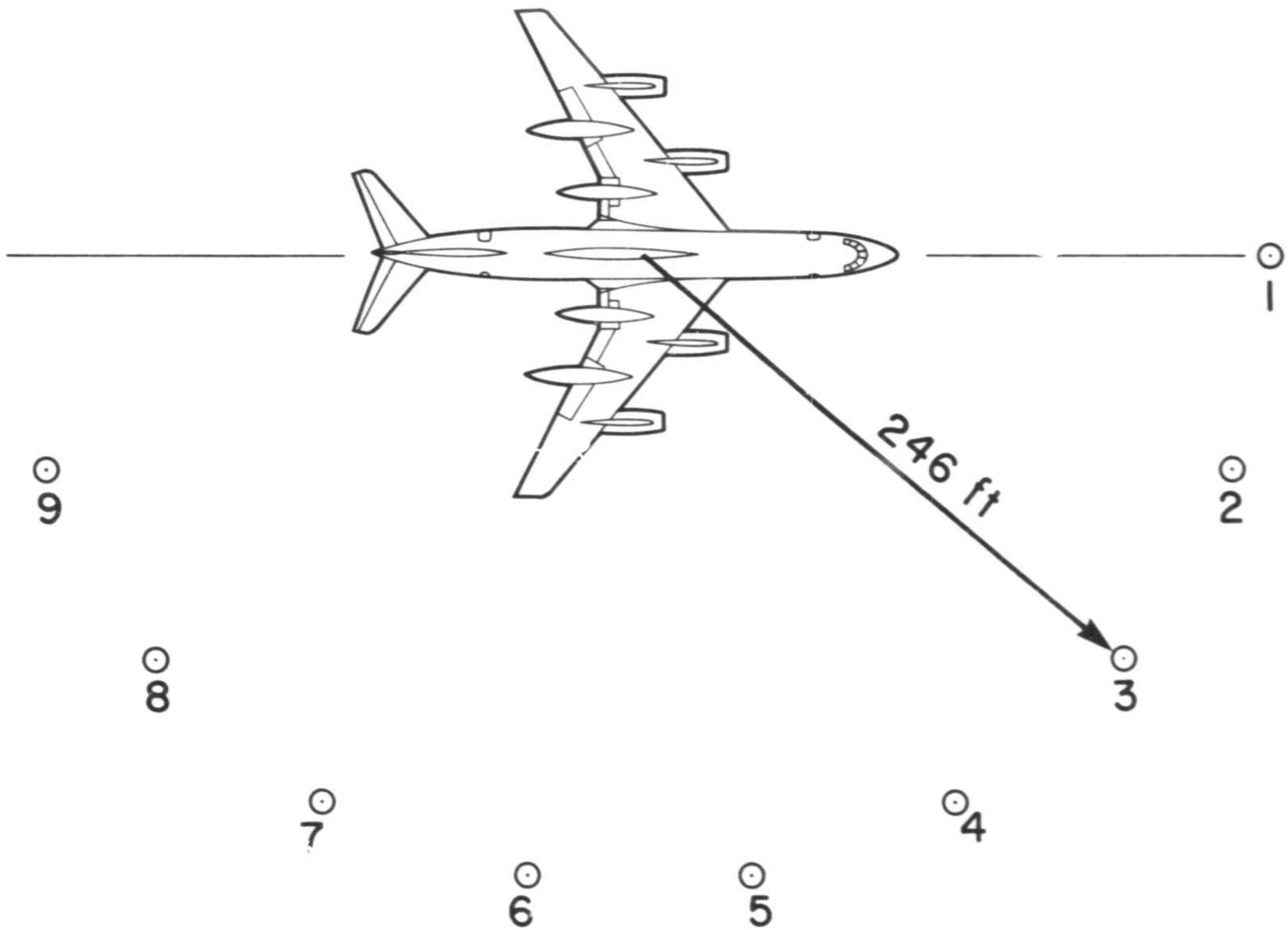

Figure 2.— Microphone layout for ground static test.

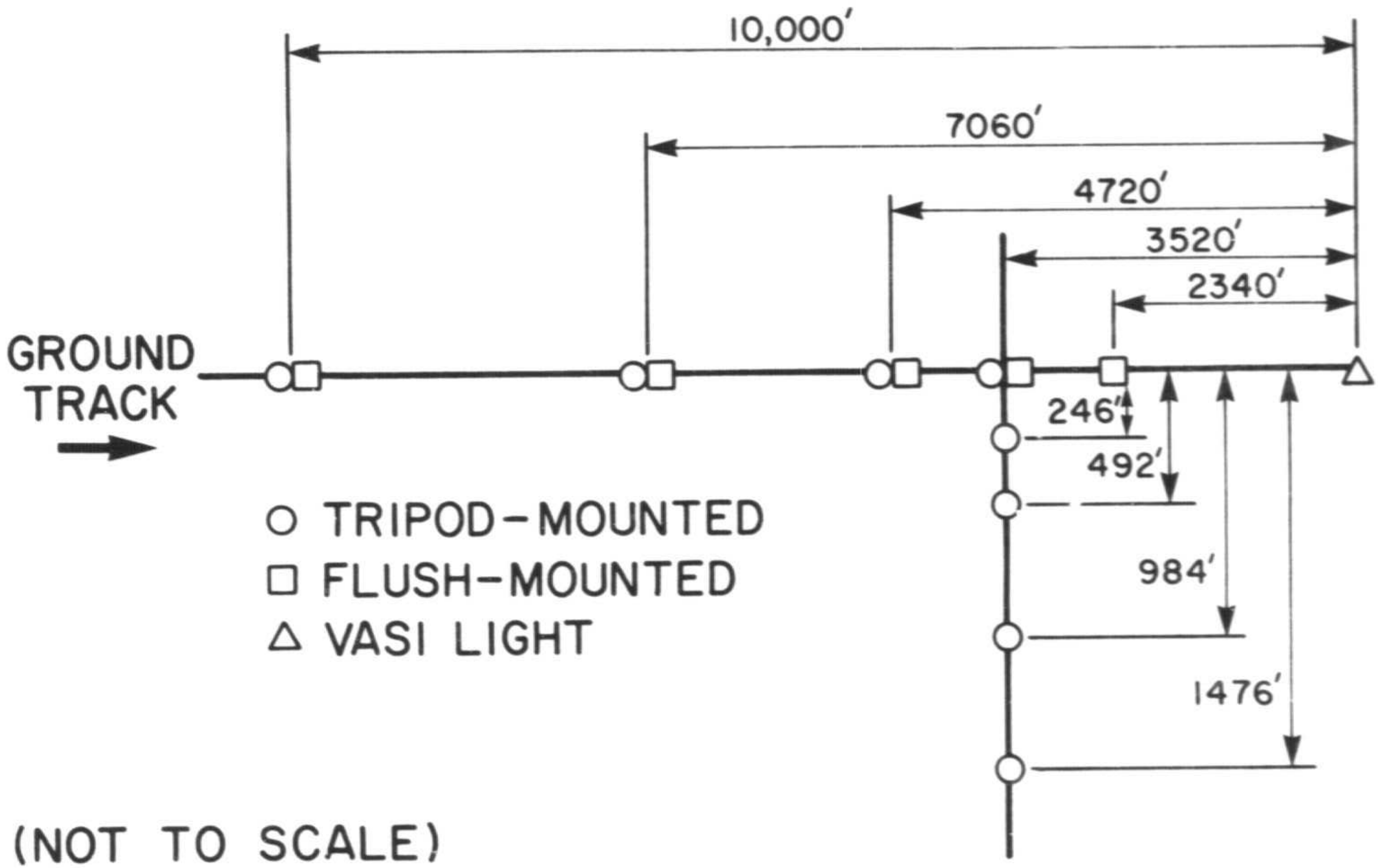

Figure 3.— Microphone layout for flight test.

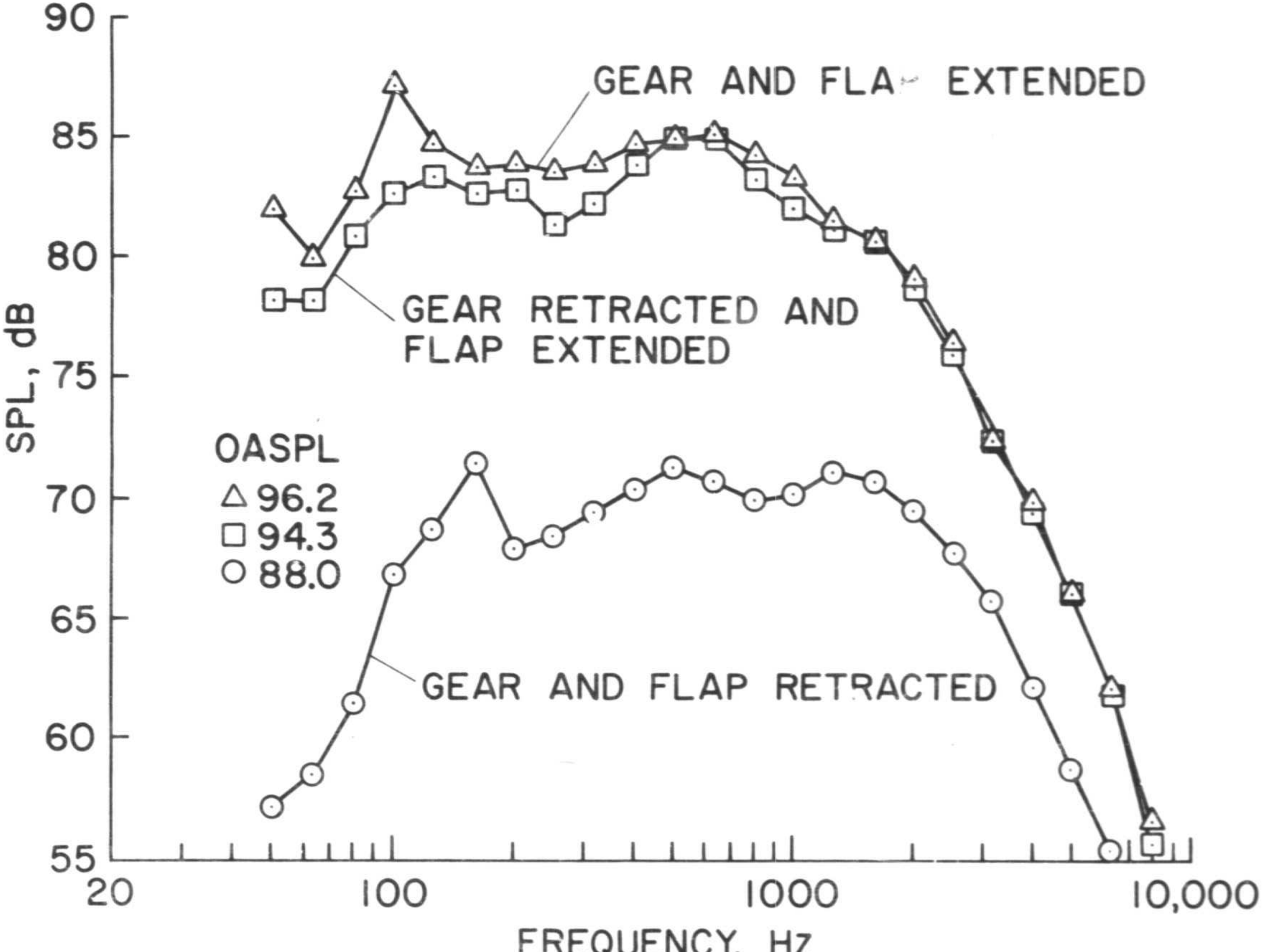

Figure 4.— Effect of gear and flap noise.

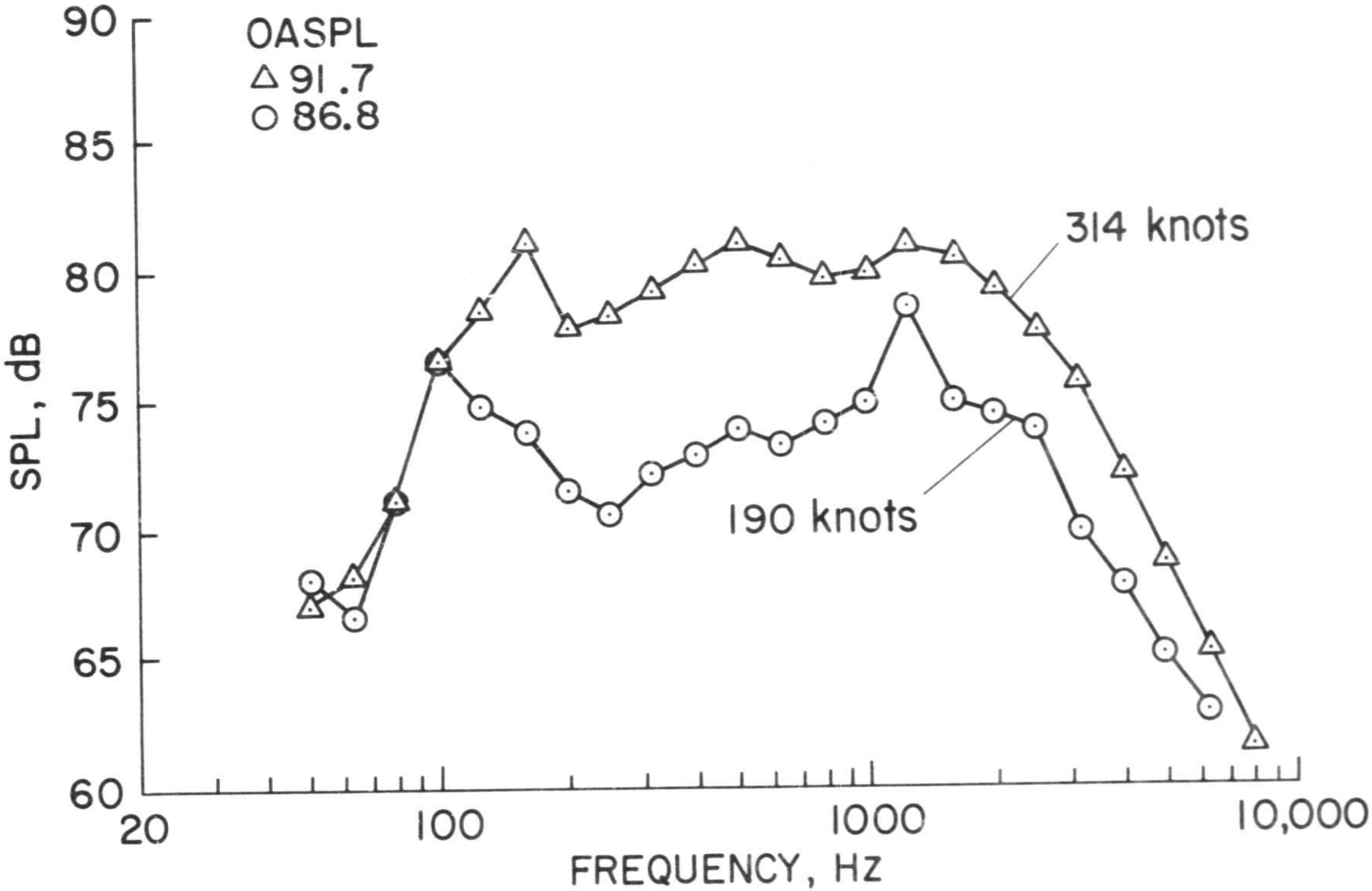

Figure 5.– Normalized spectra for clean configuration.

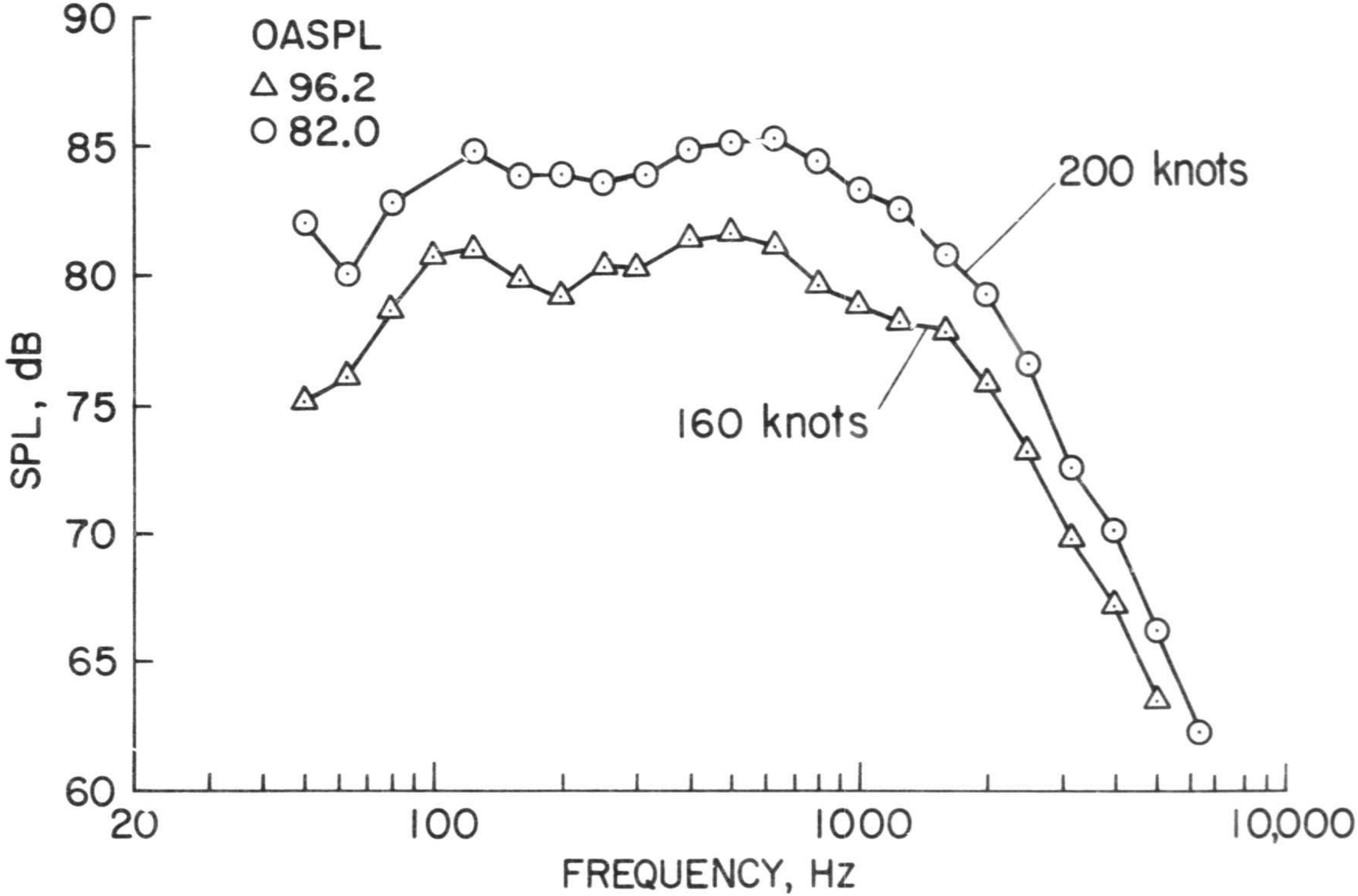

Figure 6.– Normalized spectra for landing configuration.

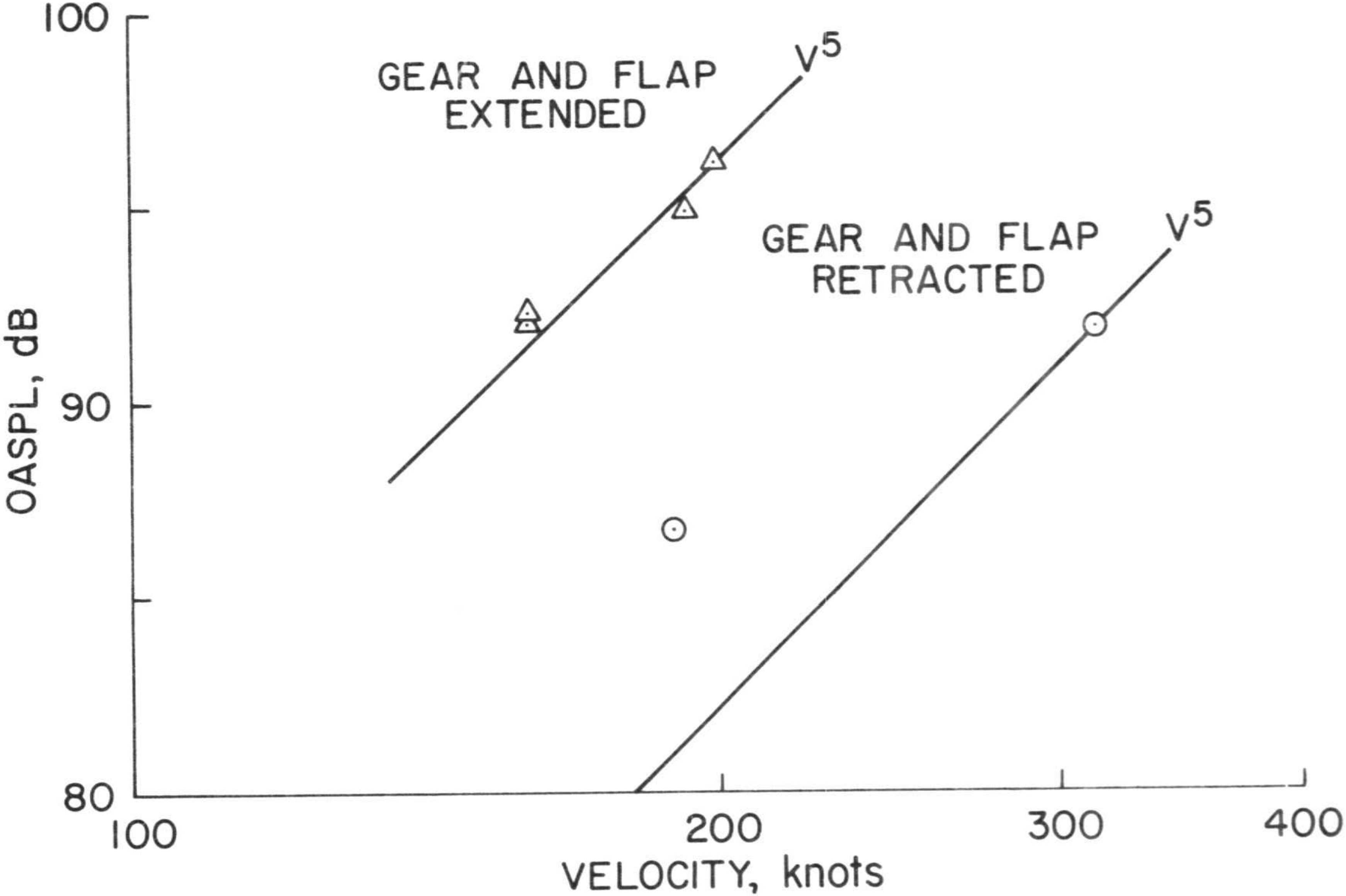

Figure 7.– Variation of OASPL with velocity.

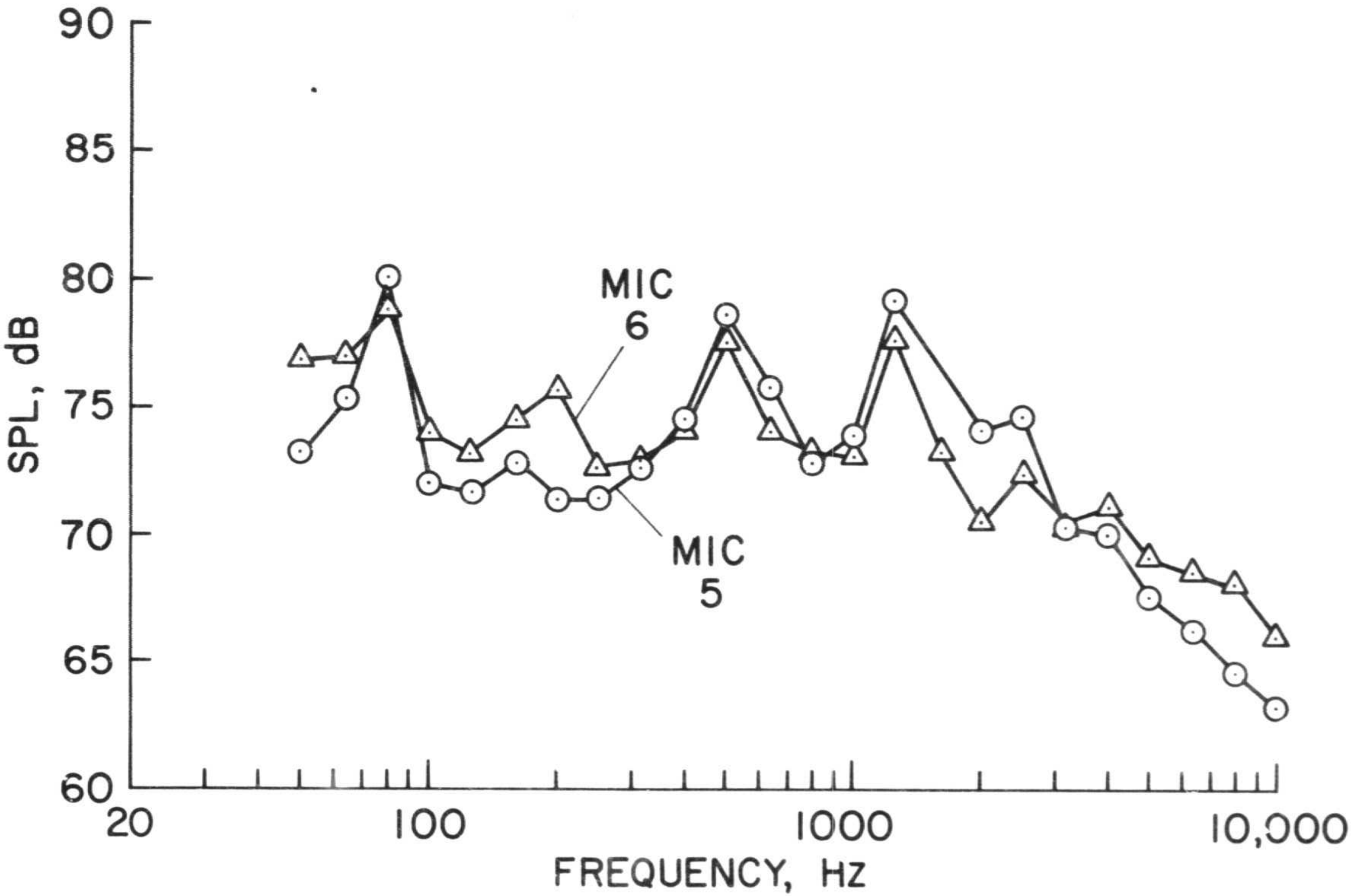

Figure 8.— Spectrum for static noise test with engines at idle power.

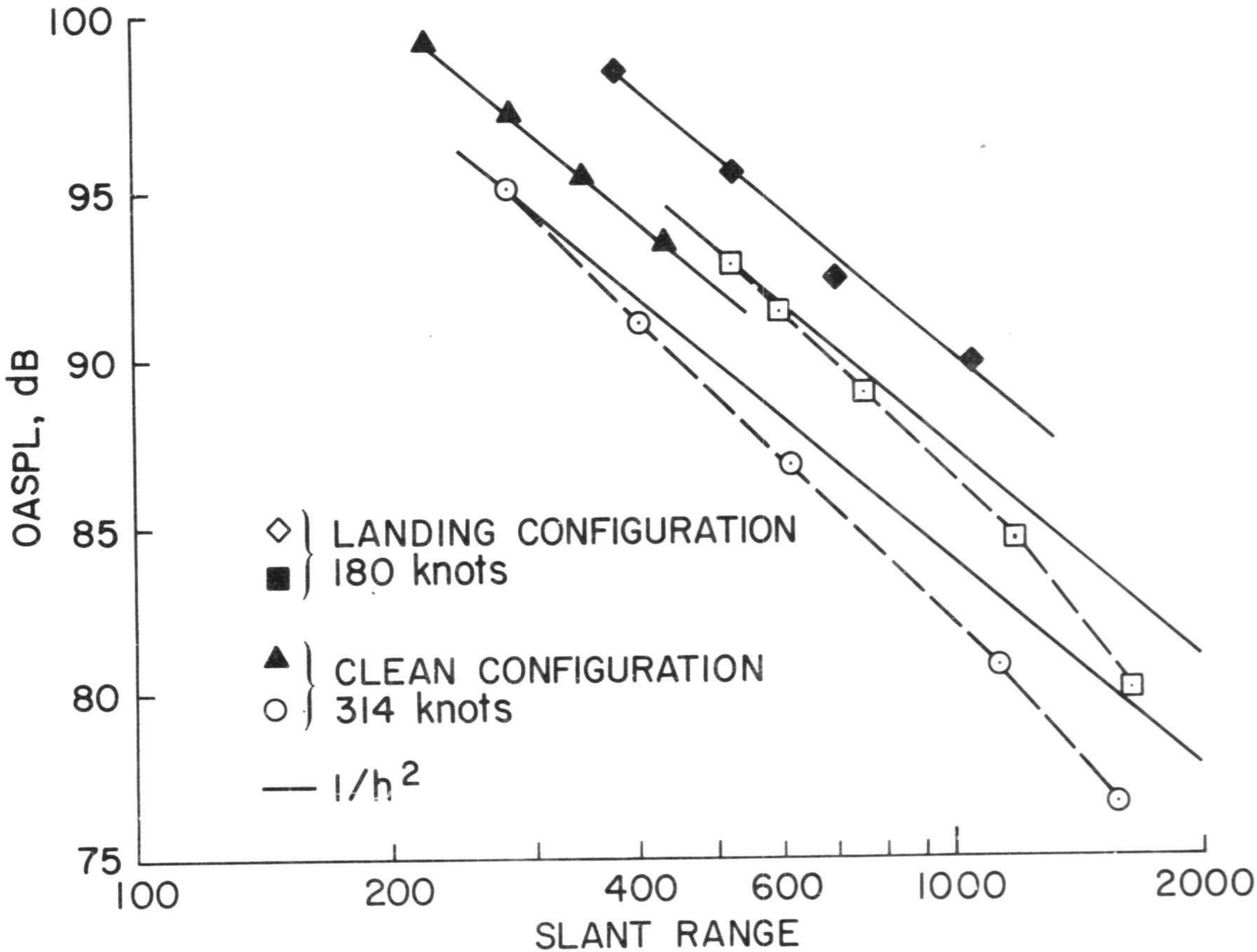

Figure 9.– Variation of airframe noise with slant range.